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ABSTRACT

The Third International Mathematics and Science Study (TIMSS) provides extensive comparisons of cross-national rankings in achievement as well as rich, descriptive analyses of the students, teachers, and schools participating in the study. In spite of the wealth of achievement and descriptive data available, the two are rarely linked in research. In this seventh issue of "Policy Issues," an empirical link is provided between the performance of eighth-grade mathematics students and the educational practices of more rigorous curricula and conceptual approaches to instruction. Relationships between achievement and educational practices, previously based on theories of best practices, are now substantiated with data. In this regard, the North Central Regional Educational Laboratory (NCREL) takes a significant step forward in using large-scale assessment data like TIMSS to help state and local policymakers make good decisions to support exemplary math performance. After providing some background, this article discusses how economic status affects achievement and how schools contribute to achievement. (Contains 11 references.) (ASK)

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New Evidence Links Curricula and Instruction to Mathematics Achievement

by
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Judy Taylor

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POLICY ISSUES

Issue 7 December 2000

How can we improve mathematics curricula and instructional approaches to support exemplary performance among U.S. students?

About This Issue

The Third International Mathematics and Science Study (TIMSS) provides extensive comparisons of cross-national rankings in achievement, as well as rich descriptive analyses of the students, teachers, and schools participating in the TIMSS. In spite of the wealth of achievement and descriptive data available, the two are rarely linked in research.

In this edition of Policy Issues, *an empirical link is provided between the performance of eighth-grade mathematics students and the educational practices of more rigorous curricula and conceptual approaches to instruction. Relationships between achievement and educational practices, previously based on theories of best practices, are now substantiated with data. In this regard, the North Central Regional Educational Laboratory (NCREL) takes a significant step forward in using large-scale assessment data like TIMSS to help state and local policymakers make good decisions to support exemplary math performance.*

More Than Social Advantage:
New Evidence Links Curricula and Instruction to Mathematics Achievement

By Blase Masini and Judy Taylor

Introduction

The poor performance of U.S. students on the Third International Mathematics and Science Study (TIMSS) has received considerable attention from both educators and the general public. Also garnering attention has been the outstanding TIMSS performance of the First in the World Consortium (FITW), a group of suburban Chicago school districts that independently administered the TIMSS to its students, with the results ranking among the best in the world. Located on Chicago's North Shore, FITW communities have substantial tax bases, high per-capita income, and high levels of educational attainment.

Districts that are not as well endowed often use these socioeconomic advantages to explain the high achievement levels of FITW districts, and others like them, as the consequence of blessings received and not effort expended. FITW administrators and teachers instead point to excellent curricula, professional development, and innovative leadership as possible reasons for exceptional achievement.

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NCREL

Such contrary opinions generate questions for policymakers. What really accounts for the difference between the TIMSS performance of U.S. students and FITW students? Do these factors translate into policy? If the contribution of educational practices is significant after accounting for students' economic status, then perhaps there are lessons to be learned from this ambitious consortium of FITW districts.

In this edition of *Policy Issues*, policymakers will find evidence of a link between good educational practices—specifically in curricula and instruction—and math performance. In addition, the North Central Regional Educational Laboratory (NCREL) isolates the contribution of socioeconomic status (SES) to student achievement to allow for a more accurate look at the contribution of curriculum and practice. Critics often dismiss gains made by students from affluent families as a natural outgrowth of their economic advantage. NCREL's analysis confirms the contribution of SES on achievement, but it also provides substantial evidence that factors beyond SES also contribute to a student's performance.

Some Background

The TIMSS was an assessment administered in 1995 in 30 languages to more than 500,000 students in 41 countries. TIMSS measured and compared students' mathematics and science knowledge and skills in Grades 4, 8, and 12. TIMSS also provided educators and policymakers with important contextual information from curriculum analyses and from teacher and student surveys.

Much has been written on the results from the TIMSS achievement test in recent years. Descriptions of the educational practices of the classrooms and schools participating in TIMSS also have been detailed. For example, the National Center for Education Statistics (NCES) has published three editions of *Pursuing Excellence*, one each for Grades 4, 8, and 12 (U.S. Department of Education, 1997, 1996, and 1998, respectively). Each edition provides a synthesis of initial findings from TIMSS to inform educators, parents, policymakers, and other education stakeholders on the strengths and weaknesses of U.S. schools from an international perspective. Separate chapters are devoted to mathematics and science achievement, mathematics and science curricula, methods of instruction, and teacher and student background.

In the TIMSS publication, *A Splintered Vision*, Schmidt et al. (1997) present substantial data on the unfocused state of the U.S. mathematics and science curricula. They conclude that poor student performance is likely a result of unfocused curricula.

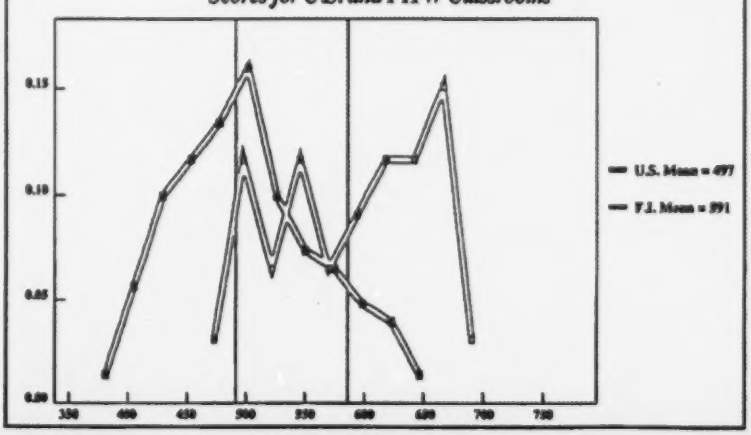
FITW districts successfully petitioned the U.S. Department of Education for the right to administer the TIMSS to their fourth-, eighth-, and twelfth-grade students. After completing this study, FITW forged a partnership with NCREL to learn how to use their TIMSS data to improve local practice.

A First Look at What We Can Learn From High-Performing School Districts (U.S. Department of Education, 1999) provides a detailed report of student achievement and teacher practices within the FITW. *First Look* also provides the first comprehensive overview of FITW student performance and an initial exploration of some of the reasons for their performance.

How Economic Status Affects Achievement

In this analysis of TIMSS data for the NCREL study, NCREL compared the average classroom performance in eighth-grade mathematics achievement for U.S. classrooms (mean = 497) and FITW classrooms (mean = 591). Average classroom

Figure 1
Distribution of Mathematics Achievement Scores for U.S. and FITW Classrooms



scores on the TIMSS mathematics test ranged from 370 to 692. The complete distributions for the U.S. and FITW are presented in Figure 1.

Factors associated with economic advantage also were considered. These included both student factors, such as the number of books in students' homes, and school factors, such as per-pupil expenditure. (A complete list of economic factors is presented in Table 1.) On average, FITW classroom achievement on the TIMSS mathematics test was 106 points higher than that of U.S. classrooms (Table 2). Economic factors accounted for 63 of the 106-point advantage enjoyed by FITW classrooms. But with 43 points remaining in the difference, clearly something beyond socioeconomic advantages is at play in FITW classrooms.

Table 1
Measures of Socioeconomic Status

Student Level:

- Number of books in student's home
- Race/ethnicity of student
- Non-English language spoken in the home
- Parental education

Classroom Level:

- Per capita income
- Percent of students eligible to receive free lunch
- Per pupil expenditure

How Schools Contribute to Achievement

Analysis of TIMSS data often implies a strong relationship between educational practices and student achievement. Indeed, most educational stakeholders hope that educational practices are related to achievement. As early as September 1997, NCREL offered a set of recommendations to policymakers based on its initial analysis of TIMSS data. In June 1999, NCREL published a second *Policy Issues* devoted to TIMSS analysis in which NCREL argued that educational practices of high-achieving schools could serve as benchmarks toward which others could strive.

Table 2

	Average Difference in Classroom Math Score
FITW Advantage	106
Attributed to Economic Status	63
Attributed to Other Factors	43

Yet it is only more recently that NCREL has confirmed the relationship between instructional practices and high achievement through empirical analyses. Several curriculum and instructional measures created from sets of teacher survey items were related significantly to mathematics achievement. (Table 3 provides a sample of survey items used to create each measure.) Furthermore, more sophisticated analyses revealed that all measures still were related significantly to mathematics achievement after taking into account the influence of economic status. A full report is available at www.ncrel.org/re/ses.

FITW and U.S. Classrooms: A Comparison

This research presents strong correlations between certain educational practices and achievement after taking SES into account. The correlations between these practices and average classroom achievement exist in all classrooms in this study, both FITW and U.S. Therefore a final question remains: Are these exemplary practices present more often in the FITW classrooms than in U.S. classrooms?

A prior descriptive study on FITW classrooms indicates that the practices associated with higher achievement in this study indeed are present in many of the FITW classrooms. This point is emphasized only as a means of sharing with others "nuggets" of good practice.

Curriculum

Among the curriculum variables, the percent of topics covered prior to eighth grade was related positively to mathematics achievement. In contrast, the percent of topics new to the eighth-grade curriculum was related negatively to mathematics achievement. *First Look* details how curricular content plays out in FITW and U.S. classrooms.

Of note, geometry and algebra topics are taught earlier in more FITW classrooms than U.S. classrooms. These same topics are presented more often as new material in U.S. classrooms (i.e., content not covered prior to eighth grade). In short, FITW teachers tend to teach in a manner associated with higher achievement by introducing more sophisticated mathematical concepts earlier in students' academic careers. Recent

Table 3
Sample Teacher Survey Items Incorporated Into Instructional Practice and Curriculum Measures

Instructional Practices

Importance and Amount of Drilling

To be good at mathematics at school, how important do you think it is for students to remember formulas and procedures?

To what degree do you agree or disagree with the following statement: If students are having difficulty, an effective approach is to give them more practice by themselves during class.

To what degree do you agree or disagree with the following statement: Mathematics should be learned as sets of algorithms or rules that cover all possibilities.

Understanding Concepts

In your mathematics lessons, how often do you usually ask students to explain the reasoning behind an idea?

To be good at mathematics at school, how important do you think it is for students to understand mathematical concepts, principles, and strategies?

To be good at mathematics at school, how important do you think it is for students to be able to provide reasons to support their solutions?

Utilization of Textbook in Teaching

When planning mathematics lessons, how much do you rely on student textbooks?

When planning mathematics lessons, how much do you rely on other textbooks or resources?

Approximately what percentage of your weekly mathematics teaching time is based on the text?

Curriculum

Percent of Topics Covered Previously

The percent of topics covered prior to Grade 8 from a list of 44 mathematics topics.

Percent of Topics New

The percent of topics introduced for the first time in Grade 8 from a list of 44 mathematics topics.

research has shown that this pattern of covering algebra in middle school is strongly associated with achievement growth throughout high school. These positive results are consistent for all students, regardless of math skills prior to entering high school (Gamoran & Hannigan, 2000).

Instruction

Among the instructional practices in this study, practices that involve drilling students were related negatively to mathematics achievement while practices that promote conceptual understanding of material were related positively to mathematics achievement. These findings provide an interesting contrast to prior research (NCREL, in press).

Both U.S. and FITW teachers believe that mathematics is best understood when students foster conceptual understanding by generalizing, synthesizing, and evaluating mathematical concepts rather than follow a structured set of steps and perform such tasks as algorithm drills. However, FITW teachers stress more conceptual understanding than U.S. teachers. In *First Look*, more FITW than U.S. teachers ask students to explain the reasoning behind an idea and write equations to represent relationships—to succeed in such tasks, conceptual understanding of material is required. Simply put, while it seems that both U.S. and FITW teachers believe conceptual understanding of material is important, other findings suggest that more FITW teachers do so in practice.

These findings indicate that both economic advantage and certain educational practices contribute to mathematics achievement. It seems that both "blessings received" and "effort expended" account for the superior performance of FITW students.

Policy Recommendations

In earlier publications of TIMSS analyses, educational researchers have used their best judgment to predict a strong correlation between educational practices and mathematics achievement. In NCREL's June 1999 *Policy Issues*, recommendations were made to "refocus the breadth and depth of the curriculum" and to "improve the balance between skill building and understanding." Now with the additional analyses, educators can support these recommendations with sound data.

Capitalize on Students' Opportunity to Learn Key Content at an Earlier Age

Support curricular programs that introduce algebra and geometry to more students at an earlier age.

This study shows that FITW students are exposed to algebra and geometry at an earlier age than their U.S. peers. That students exposed to algebra and geometry did well on the TIMSS test should be expected; the

TIMSS test is weighted with geometry and algebra items. Of particular significance to policymakers is that U.S. students might have performed significantly better had they also received algebra and geometry instruction at an earlier age, as did their FITW peers. In the end, the issue for policymakers should not be performance on the TIMSS test per se, but rather the implications of failure—a constraint on students' ability to compete in an international job market.

Mathematics curricula from kindergarten to eighth grade should include rigorous content: Pre-algebra and pre-geometry content should be a priority, along with intensive coverage of basic content—such as numeration, whole numbers, and fractions—in the early grades. With this approach, basic content can be mastered and then removed from the curriculum, giving students more time to master advanced concepts. One nationally recognized example of such a curricular program is the *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics [NCTM], 2000).

This type of curricular reform also brings with it a new philosophy and efficiency. Rather than spiraling content throughout the curriculum, teachers and students should be held accountable for teaching and learning content in a more efficient manner. As stated in NCREL's June 1999 *Policy Issues*, "less content taught well, and in more depth, lends itself to greater understanding." (See the sidebar on the curriculum mapping Web site designed by NCREL to facilitate curricular reform.)

Emphasize Conceptual Understanding Over Skill Building

Support instructional standards that emphasize a deep conceptual understanding of mathematics concepts rather than mere skill building.

Early exposure to algebra and geometry is necessary but not sufficient in and of itself. *How* this material is taught is also significant. U.S. and FITW teachers alike believe that providing deep conceptual understanding of mathematics concepts is more important than building skills. However, FITW teachers are more likely to put these beliefs into instructional practice.

Geometry and algebra are taught earlier in more First in the World Consortium classrooms than in U.S. classrooms.

All students need opportunities to think about mathematics concepts. They need to write about their ideas, justify their solutions, and explore strategies for solving math problems. FITW teachers tend to teach with these principles in mind: They ask probing questions and invite students to discuss the reasoning behind their solutions and problem-solving strategies. In other words, FITW teachers emphasize "comprehension over coverage, mastering ideas over learning symbols, and focusing engagement and inquiry over procedure" (Slowinski, Laine, & van der Ploeg, 1999, p. 7).

NEW!

NCREL Curriculum Mapping Web Site

NCREL and the U.S. TIMSS National Research Center have launched an interactive web site designed to assist school districts in their efforts to map out new K-8 mathematics and science curricula.

Users are prompted to map their mathematics and/or science curriculum by indicating which topics are taught currently in which grade levels across a framework of 44 mathematics and 79 science topics. Users then are guided through a series of analyses, complete with a set of displays that superimpose their curriculum against that of top-achieving TIMSS nations.

The site is available at: ***www.ncrel.org/currmap***

Again, the *Principles and Standards for School Mathematics* (NCTM, 2000) provides a good example. In addition to requiring mastery of algebra and geometry by eighth grade, these standards also list rigorous activities that require conceptual rather than algorithmic approaches to problem solving.

Strengthen Professional Development for Teachers

Invest in professional development for teachers that will effect conceptual understanding for students, improve standards alignment, and improve teachers assessment capacity

U.S. and FITW teachers seem to agree on what is needed to transform mathematics instruction. However, U.S. teachers appear to lack the support to learn how to make the trans-

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*To order a free copy of this report, entitled *An Exploratory Analysis of School-Based Student Assessment Systems*, call our toll-free order number (800) 356-2735. Quantities are limited.

formation happen. More intensive professional development is needed to help U.S. teachers translate their beliefs into practice.

Teachers need ongoing opportunities to reflect on their practice, observe and coach colleagues, and model instructional techniques that emphasize conceptual understanding of math principles and strategies (Darling-Hammond & Falk, 1997). In addition, schools and school districts must align instruction with standards and appropriate assessments. Darling-Hammond and Falk (1997) argue that such systemwide re-engineering would help a great deal in raising achievement for all students.

Teachers need to gain greater mathematics content understanding, have a clear and coherent standards approach to instruction, and develop capacity for using assessment tools to identify and correct gaps in student learning early on. Simply put, for U.S. schools to be more competitive internationally, teachers need ongoing and engaging professional development opportunities. Teachers then will be able to provide students with exemplary instruction that aligns with both standards and assessments. This approach requires sustained investment by local and state policymakers.

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FACT SHEET

Executive Summary

More Than Social Advantage: New Evidence Links Curricula and Instruction to Mathematics Achievement

The poor performance of U.S. students on the Third International Mathematics and Science Study (TIMSS) has received considerable attention from both educators and the general public. Also garnering attention has been the TIMSS performance of the First in the World Consortium (FITW), a group of suburban Chicago school districts that independently administered the TIMSS to its students, with the test results ranking among the best in the world. Located along Chicago's North Shore, FITW communities have substantial tax bases, high per-capita income, and high levels of educational attainment.

Critics often dismiss gains made by students from affluent families as a natural outgrowth of their economic advantage. The North Central Regional Educational Laboratory (NCREL) isolated the contribution of socioeconomic status to student achievement to allow for a more accurate look at the contribution of curriculum and practice. An empirical link was found between the math performance of Grade 8 students and more rigorous curricula and conceptual approaches to education. A full report is available at ***www.ncrel.org/re/ses***.

Key Findings

- **Socioeconomic Status**
  Factors associated with economic advantage, such as the number of books in students' home and school districts' per-pupil expenditure, do account in part for FITW students' 106-point math score advantage over U.S. students. But of those 106 points, only 63 can be attributed to economic status factors. Such factors as school curriculum and classroom instruction practices appear to relate to student achievement.
- **Curriculum**
  Analysis in this study shows that eighth-grade FITW students are exposed to algebra and geometry at an earlier age than their U.S. peers. That students exposed to algebra and geometry did well on the TIMSS test should be expected; the TIMSS test is weighted with geometry and algebra items.
- **Instructional Practices**
  Exposure to algebra and geometry by the eighth grade is not sufficient in and of itself: How this material is taught is also significant. This study found that practices that involve drilling students were negatively related to mathematics achievement while practices that promote conceptual understanding of material were positively related to mathematics achievement.
- **Teacher Development**
  The study shows that U.S. and FITW teachers alike believe that providing deep conceptual understanding of mathematics concepts is more important than simply developing skills; however, FITW teachers were more likely to put these beliefs into actual instructional practice.

Policy Recommendations

The key issue for policymakers should not be performance on the TIMSS test per se, but rather the implications of failure—a constraint on students' ability to compete in an international job market. The following measures can help ensure that U.S. students will not be left behind.

- **Capitalize on opportunities for students to learn key content at an earlier age**
  K-8 mathematics curricula should include rigorous content. Pre-algebra and pre-geometry content should be a priority. There also needs to be intensive coverage in the early grades of basic content such as numeration, whole numbers, and fractions. Upon completing the eighth grade, students should be proficient in both algebra and geometry.
- **Emphasize conceptual understanding over skill building**
  Standards should require conceptual, rather than algorithmic, approaches to mathematics instruction. All students need opportunities to think about mathematics concepts: They need to write about their ideas, justify their solutions, and explore strategies for solving math problems.
- **Strengthen professional development for teachers**
  U.S. teachers need ongoing and engaging professional development opportunities. Teachers need to gain greater mathematics content understanding, have a clear and coherent standards approach to instruction, and develop capacity for using assessment tools to identify and correct gaps in student learning early on. Such professional development for teachers requires sustained investment by local and state policymakers.

For more information, contact:

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What is NCREL?

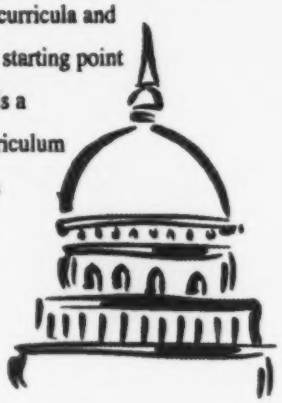
North Central Regional Educational Laboratory (NCREL) is one of ten federally funded regional educational laboratories serving the needs of students and educators across the United States. NCREL specializes in technology integration and serves the upper-midwestern region of the country.

For over 10 years, NCREL has developed and delivered products and services for K-12 educators. For example, our *Pathways to School Improvement Web* site (**www.ncrel.org/pathways.htm**) receives over 1,200 visitors daily and our *Learning With Technology* course helps practicing teachers integrate technology into the curriculum in meaningful ways. We invite you to visit our Web site (**www.ncrel.org**) for more information on these and many other resources.

For more information on aligning standards and curriculum, see NCREL Critical Issue: Integrating Standards into the Curriculum

ncrel.org/sdrs/areas/issues/content/currclum/cu300.htm

The recommendations in this *Policy Issues* address the rigor of mathematics curricula and instruction. An important starting point for improving education is a carefully thought-out curriculum that reflects the standards and goals for which the education community is willing to be held accountable.



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